

Soft QCD at Tevatron

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on behalf of the CDF and DØ collaborations

OUTLINE:

MOTIVATIONS / CONTENTS

ANALYSES / RESULTS

SUMMARY

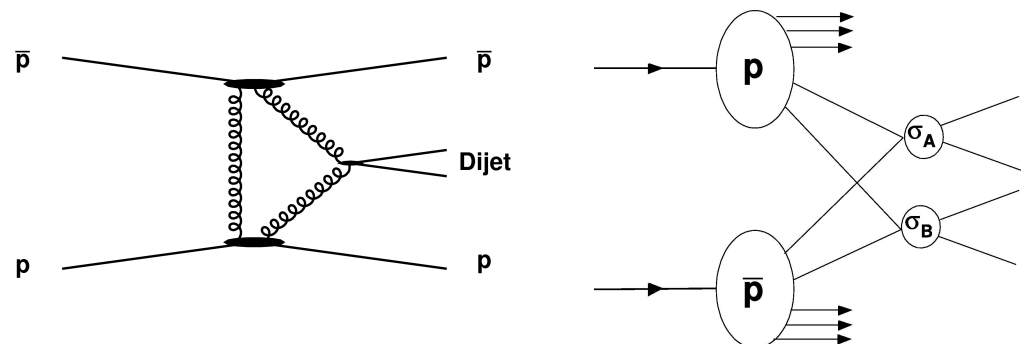
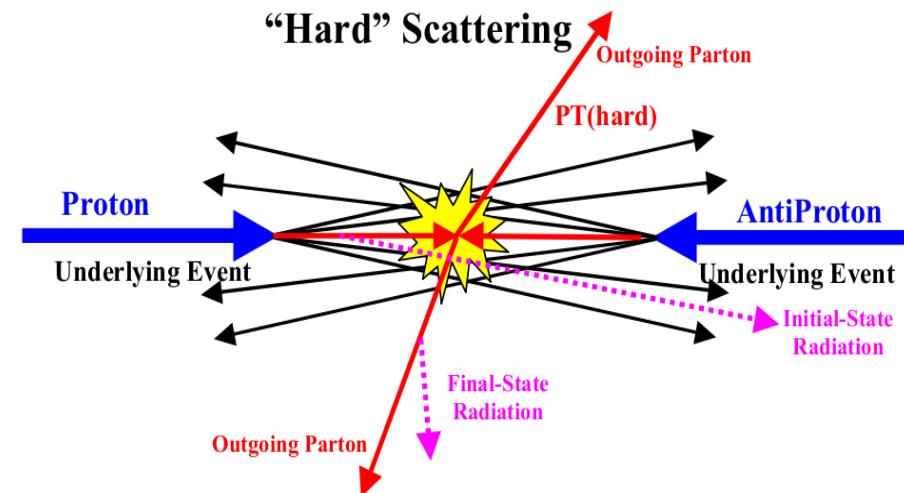


MOTIVATIONS

- Soft QCD is present in **every** hadron collider event.
- Understanding of the **interplay between the soft and the hard** interactions is necessary for rare processes searches.
- Make **Tevatron** \rightarrow **LHC** extrapolations more reliable.

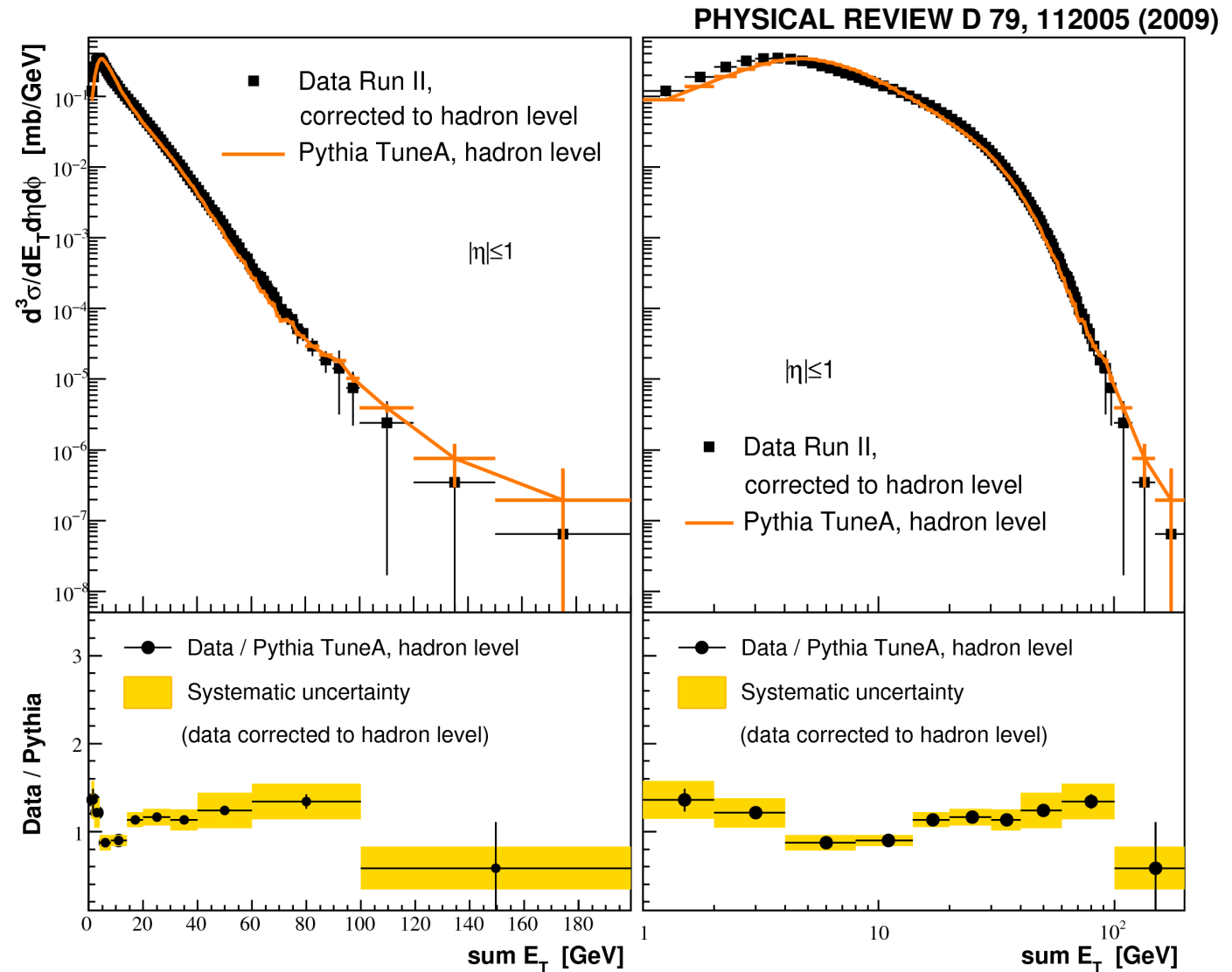
CONTENTS

1. Minimum Bias Studies
2. Underlying Event Measurements
3. Double Parton Interaction
4. Exclusive Diffractive Production



1. MINIMUM BIAS CROSS SECTIONS

- Minimum Bias = MB = inelastic interactions.
- At Tevatron, MB is dominated by soft processes.
- Observables are corrected to hadron level and compared to Pythia.

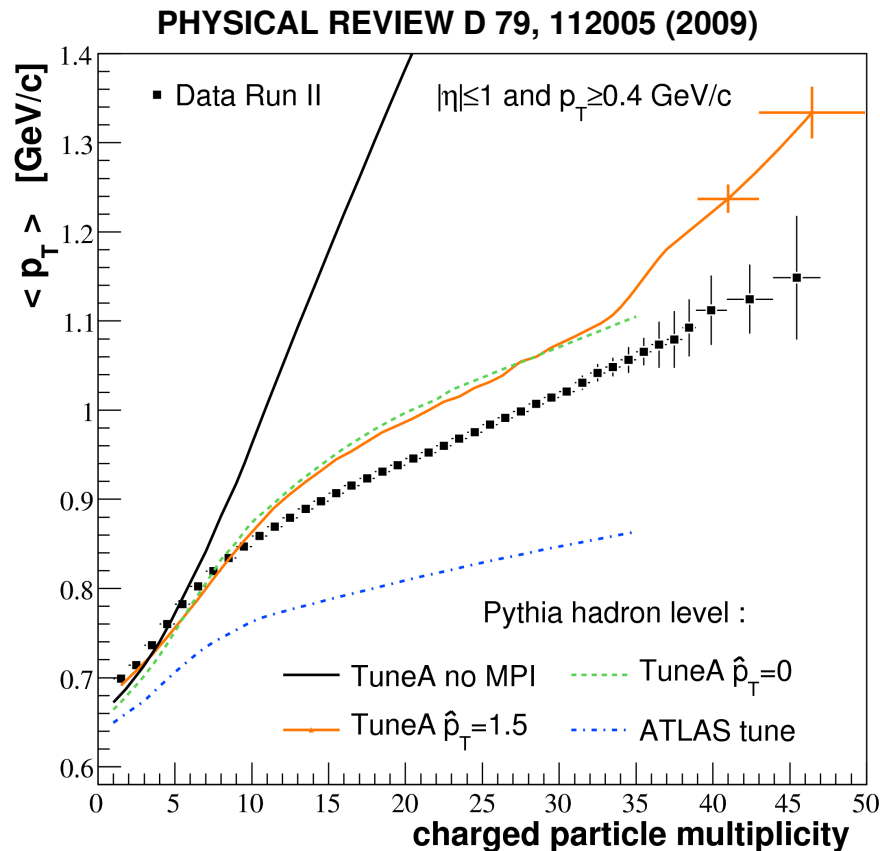


→ Measurement of
neutral particle activity.
→ Pythia prediction is
shifted.

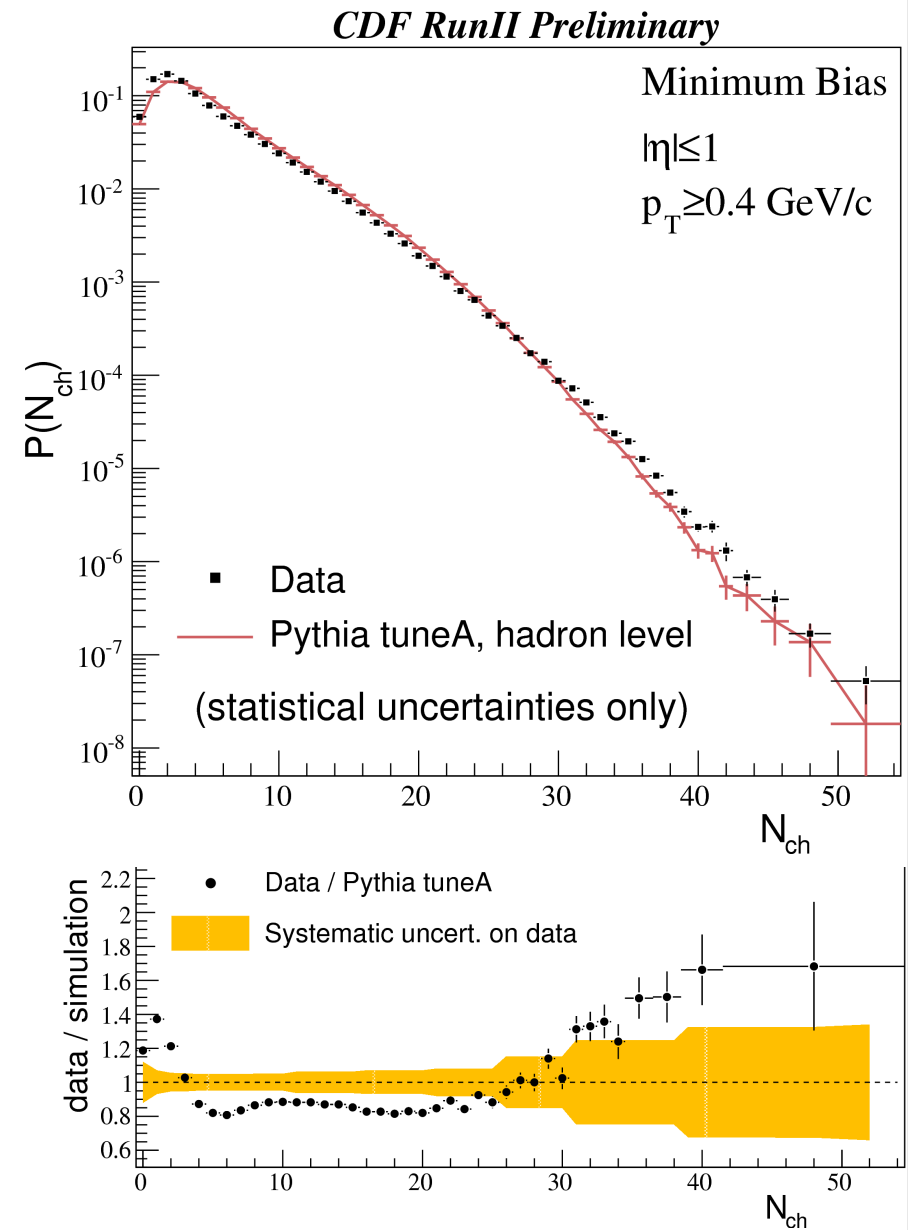
1. MINIMUM BIAS MULTIPLICITIES



→ Multiplicities are sensitive distribution to perturbative / non-perturbative effects and to multiple parton-parton interactions.



→ Data **favours** the presence of multiple parton interactions (MPI) and **can be used** to constrain MPI models for a **more reliable** extrapolation to **LHC energies**.

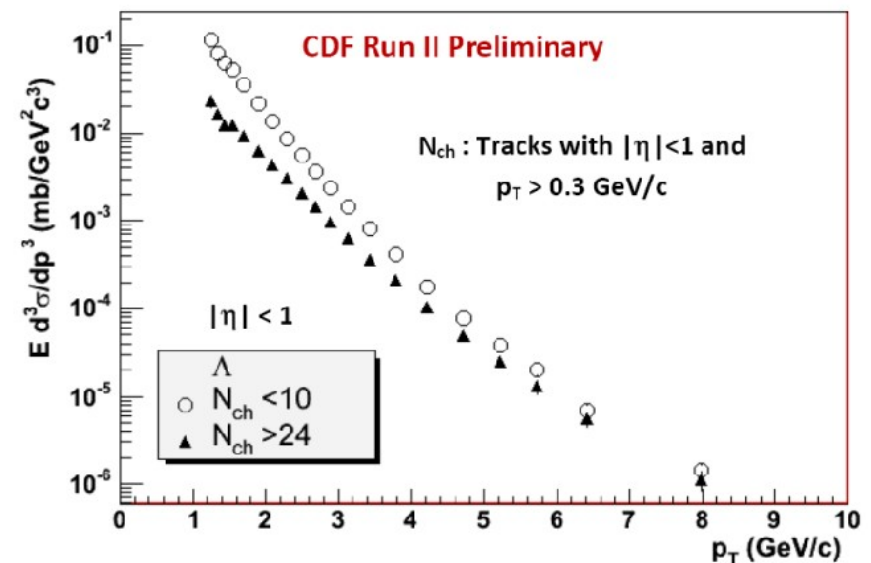
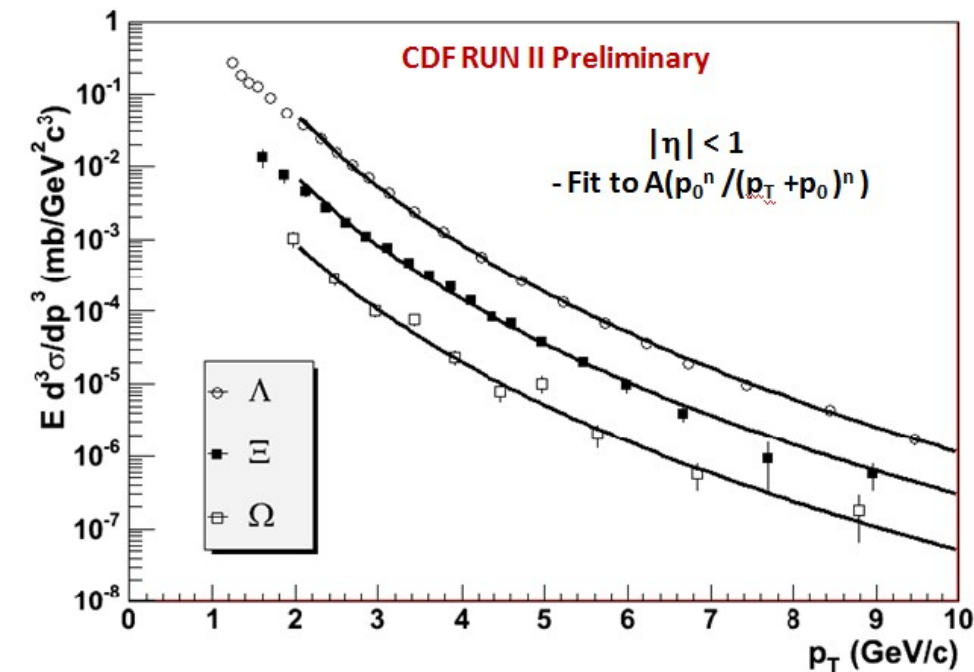
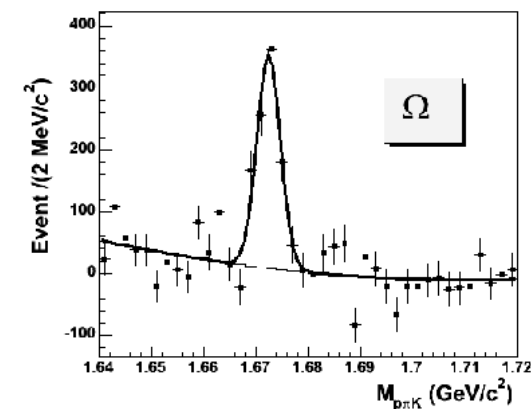
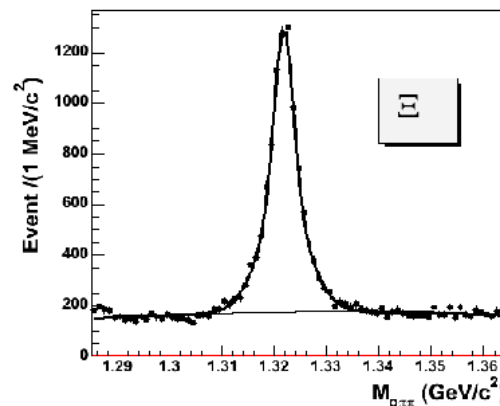
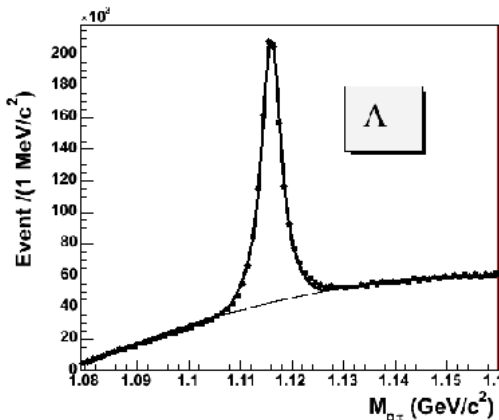


http://www-cdf.fnal.gov/physics/new/qcd/minbias_mult09/Multiplicity_Public.pdf

1. MINIMUM BIAS – HYPERON PRODUCTION

→ Strange particle production **can reveal** mechanisms from the collision.

CDF Run II Preliminary



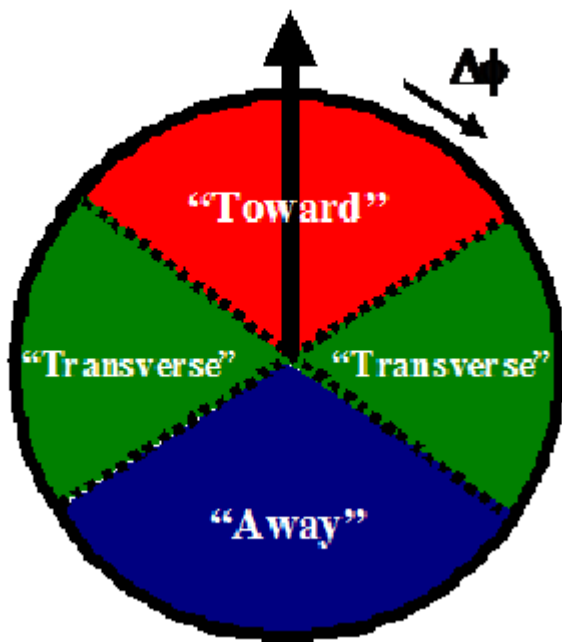
→ Cross sections are measured in p_T bins, accessing **previously unexplored** high p_T regions.

→ Cross sections are also measured in different **multiplicity** regions.

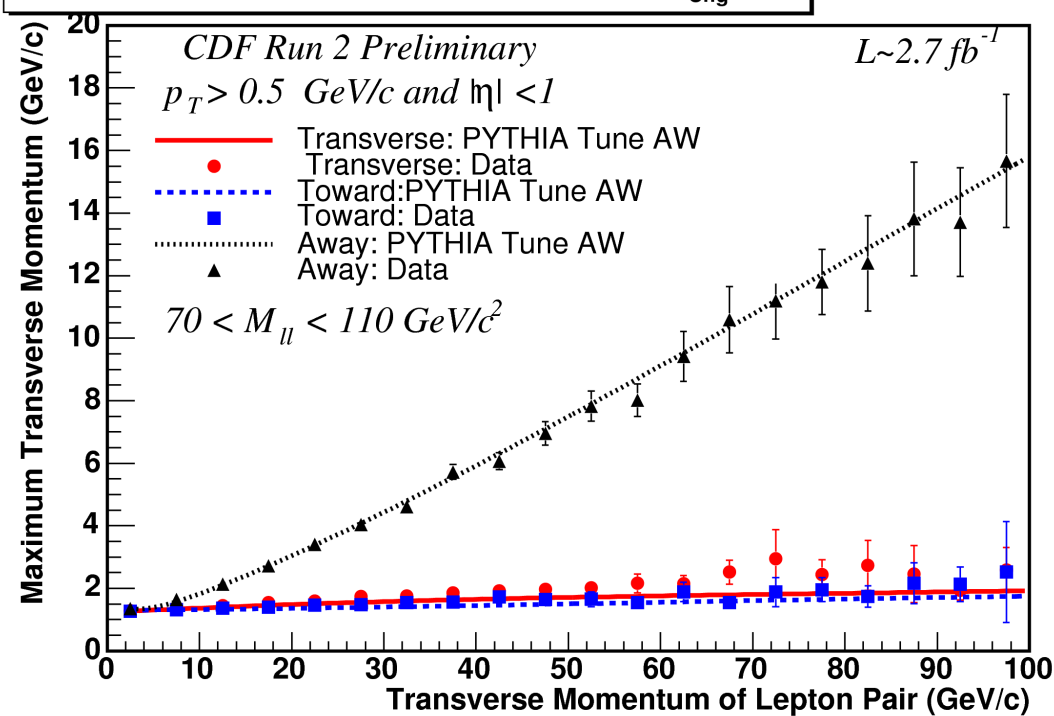
2. UNDERLYING EVENT

- Underlying Event = UE = **everything** in the event **except** the hard scattering.
- Jets and Drell-Yan events are used to study UE.
- **Goal**: Improve the understanding of high energy collider events.

Z- boson or jet Direction



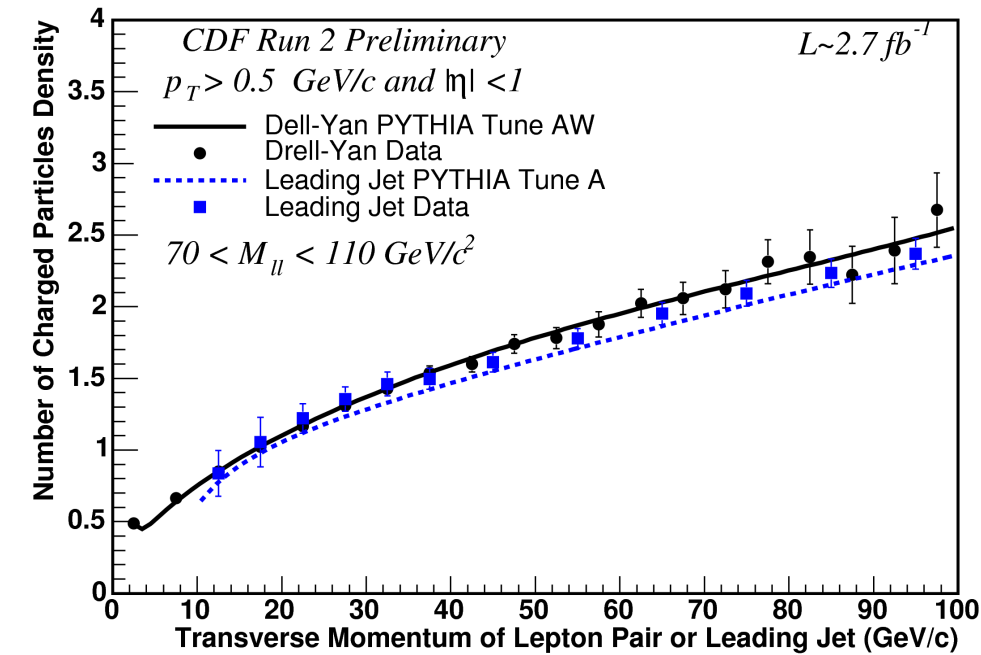
All Three Regions Charged p_T Maximum ($N_{\text{Chg}} > 0$)



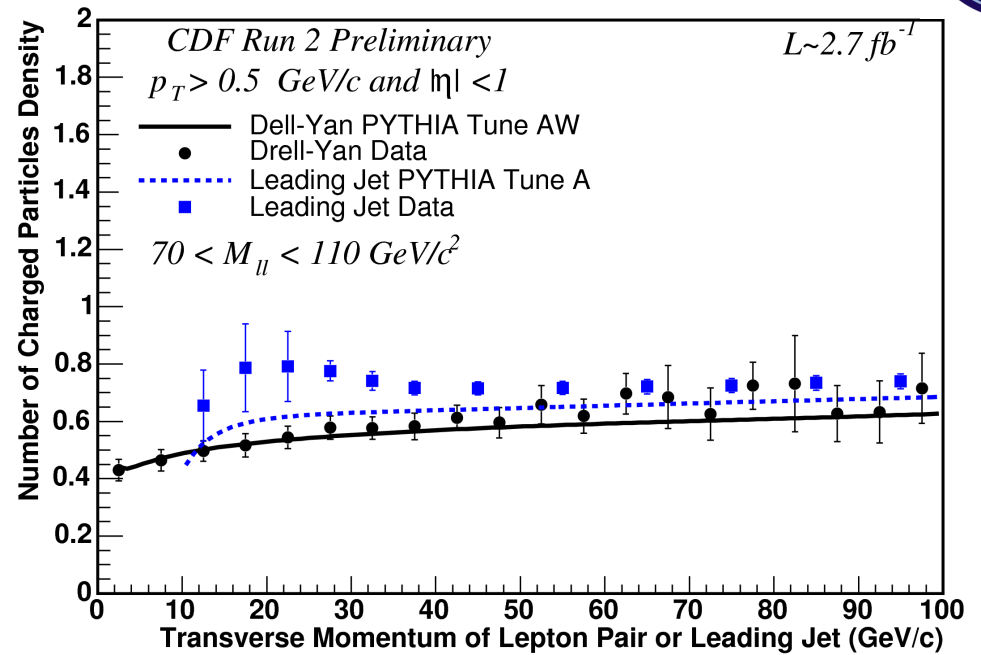
- Three regions compared.
- Looked at various variables and Pythia Tune AW **describes well** the data.

2. UNDERLYING EVENT

Away Region Charged Particle Density: $dN/d\eta d\phi$

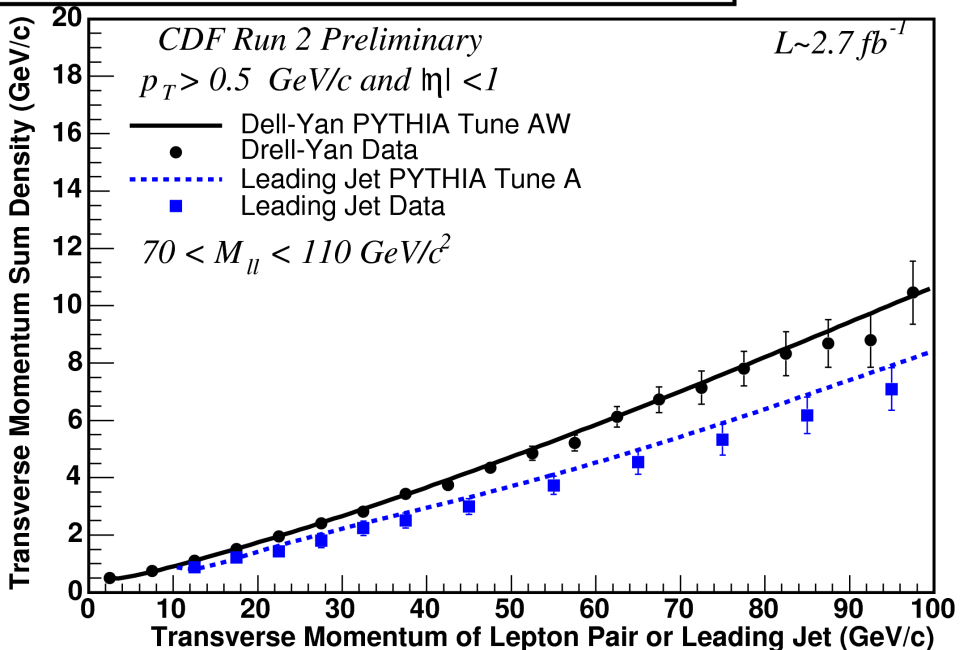


Transverse Region Charged Particle Density: $dN/d\eta d\phi$



- Jets and DY have **similar trend**.
- Reasonably **modeled** by Pythia.
- These results can be used for **MC tuning and developments**.

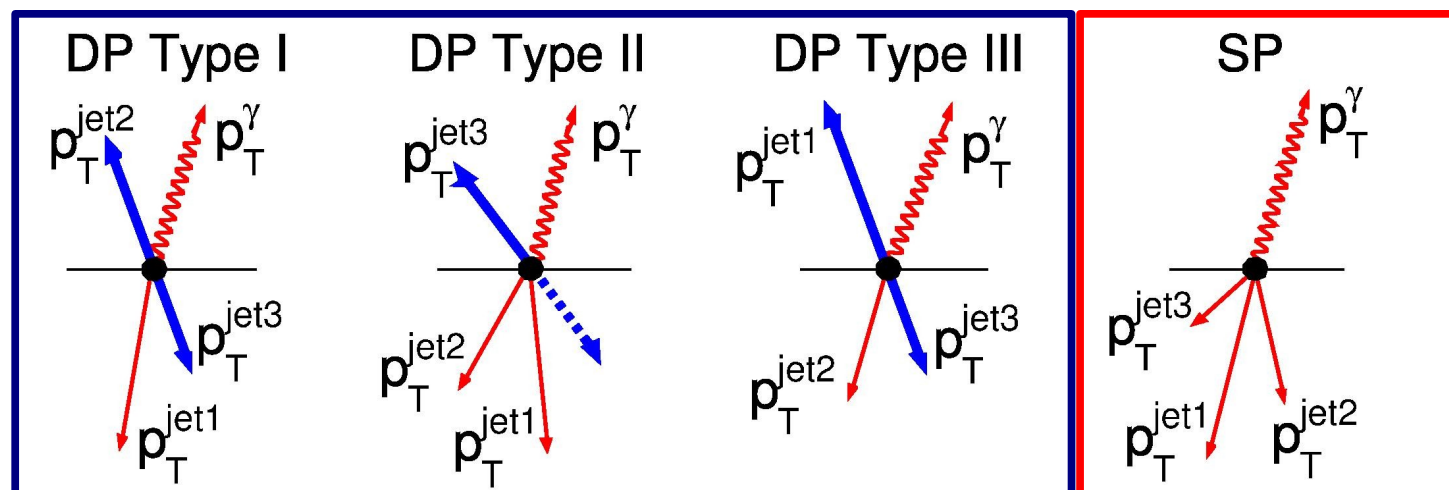
Away Region Charged p_T Sum Density: $dp_T/d\eta d\phi$





3. DOUBLE PARTON INTERACTIONS

- Provide **complementary** information about proton structure.
- **Background** to rare processes.

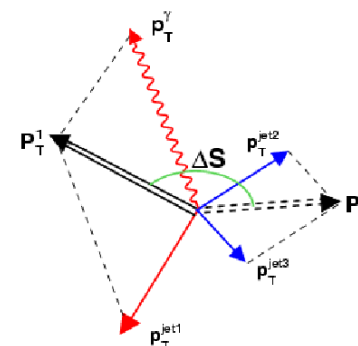


Signal

Background

$$\sigma_{DP} = \frac{\sigma_A \sigma_B}{\sigma_{eff}}$$

- Double Parton is modeled from data.
- A discriminant variable is constructed using the azimuthal angles.
- Cross section is measured in p_T bins of **2nd jet**, because **signal cross section falls faster than background** with respect to this variable.



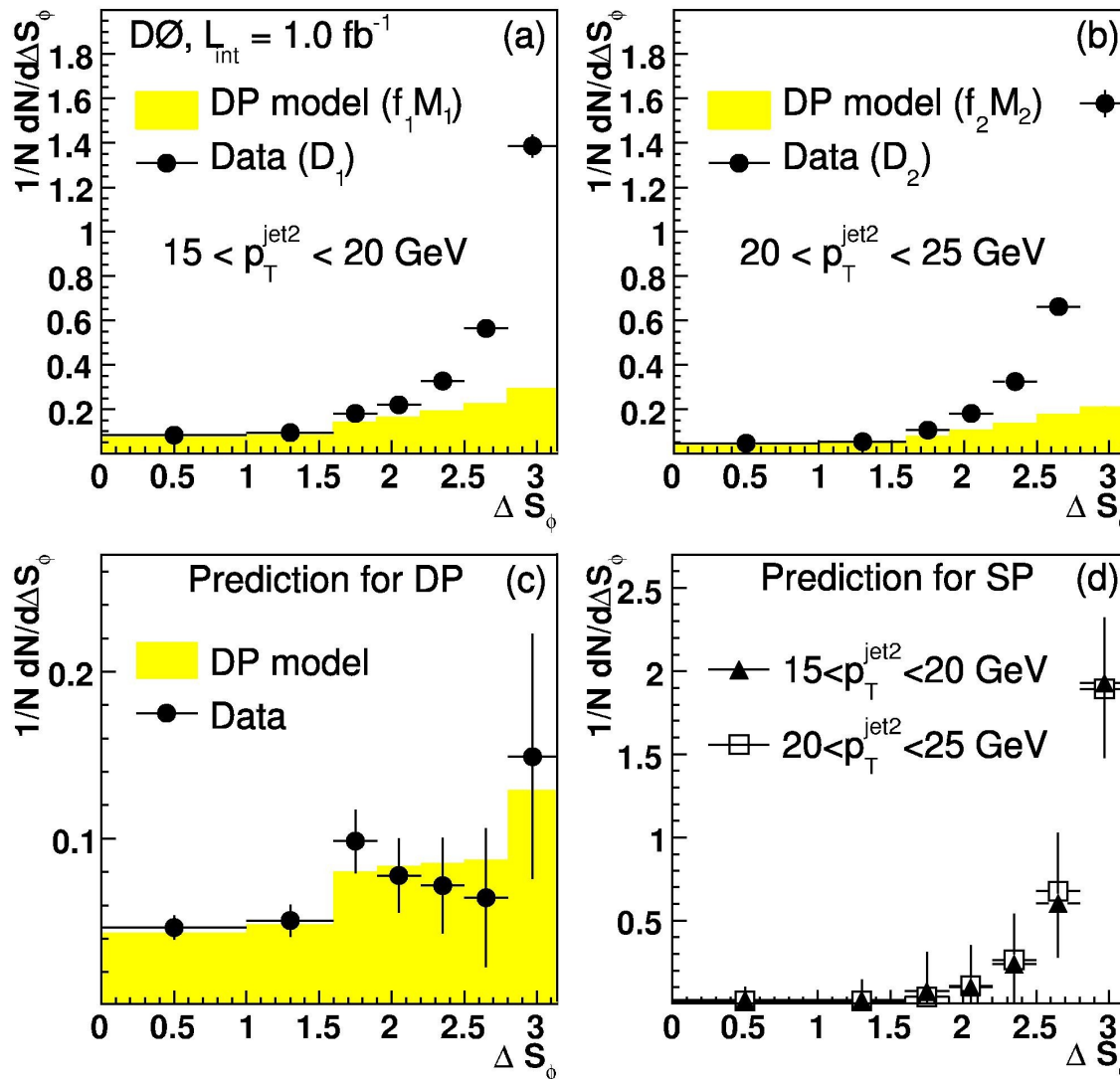
$$\Delta S = \Delta\phi \left(\mathbf{p}_T^{\gamma, jet_i}, \mathbf{p}_T^{jet_j, jet_k} \right)$$

$\Delta\phi$ - an azimuthal angle between two best p_T -balanced pairs.

3. DOUBLE PARTON INTERACTIONS



arXiv:0912.5104 [hep-ex]



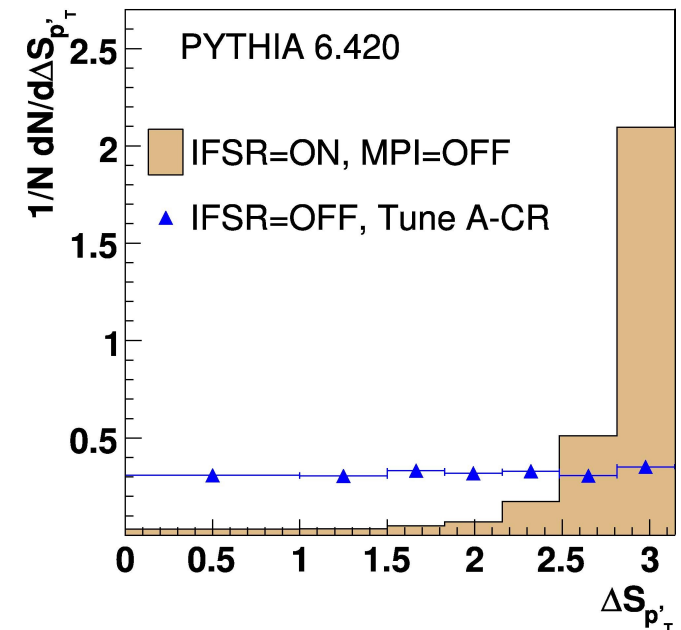
Dataset1: 2nd jet p_T : 15-20 GeV

Dataset2: 2nd jet p_T : 20-25 GeV

→ DP fraction in bin 15-20 (**f1**) is the **only unknown**.

→ **Good agreement** between data and DP model.

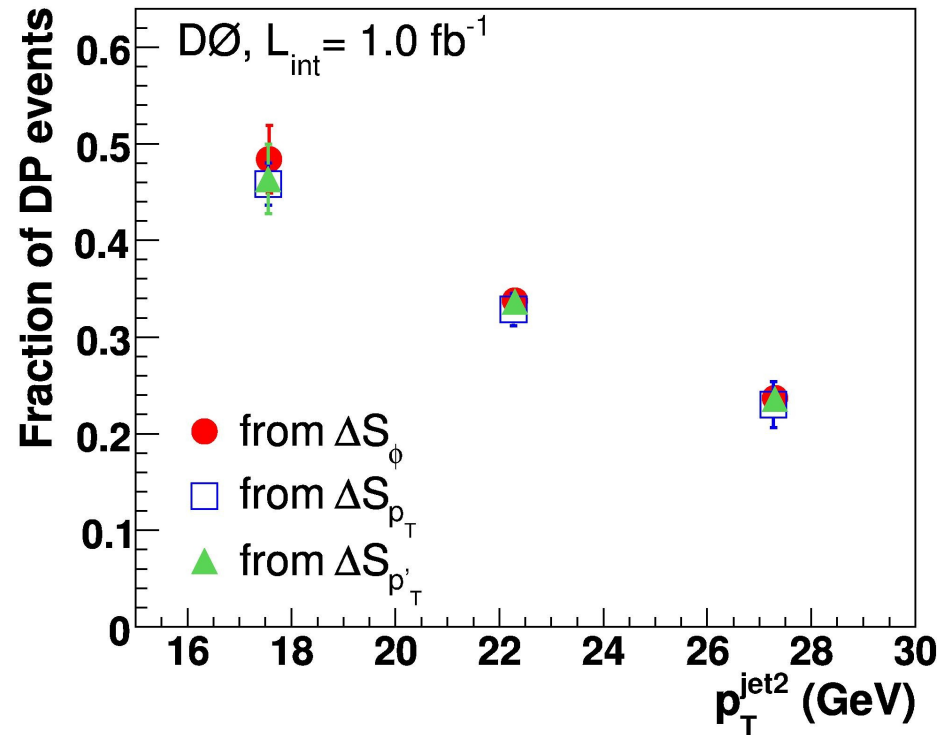
→ Discriminant variable is **well modeled** by Pythia.



3. DOUBLE PARTON INTERACTIONS



arXiv:0912.5104 [hep-ex]

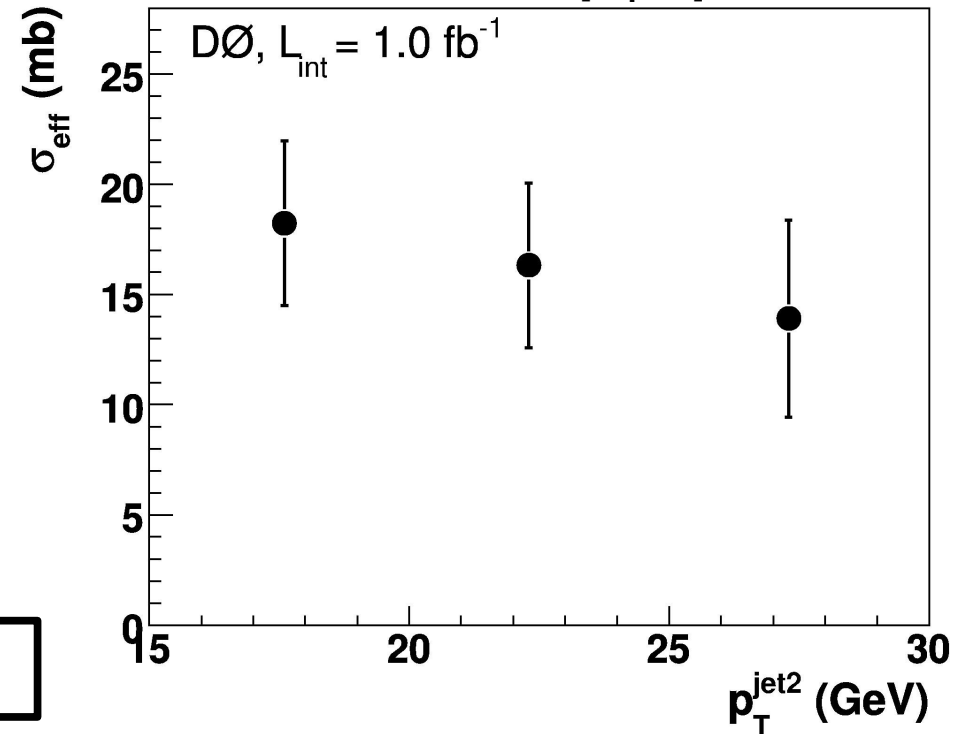


Fraction of DP events decreases as expected.

$$\sigma_{\text{eff}}^{\text{ave}} = 16.4 \pm 0.3 (\text{stat}) \pm 2.3 (\text{syst}) \text{ mb}$$

Effective cross section is approximately **constant** across p_T bins, and it is in **agreement** with previous CDF measurement.

arXiv:0912.5104 [hep-ex]



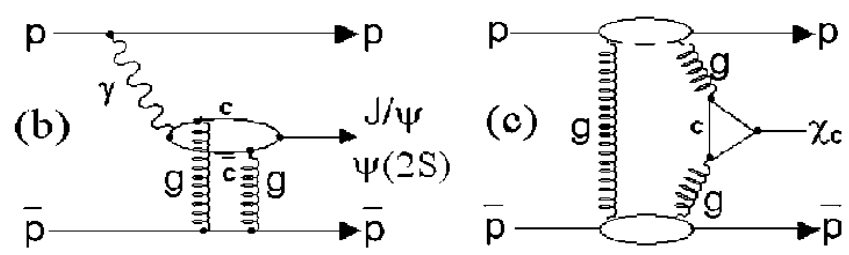
$$14.5 \pm 1.7^{+1.7}_{-2.3} \text{ mb}$$

Phys. Rev. Lett. 79, 584

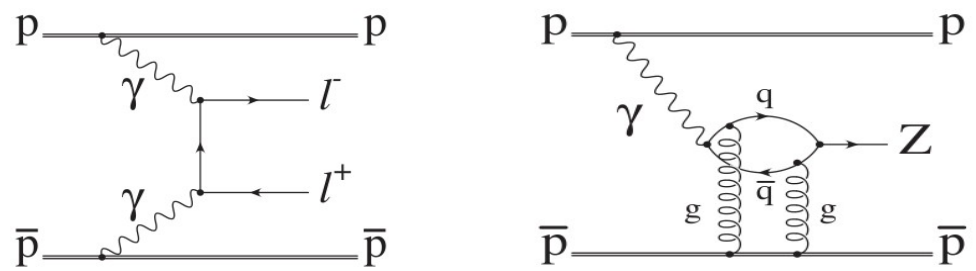
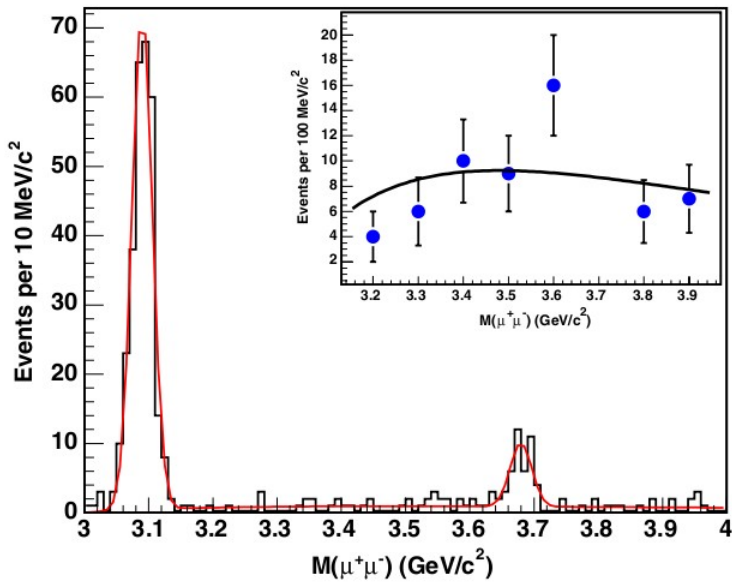
Phys. Rev. D 56, 3811

4. EXCLUSIVE PRODUCTION

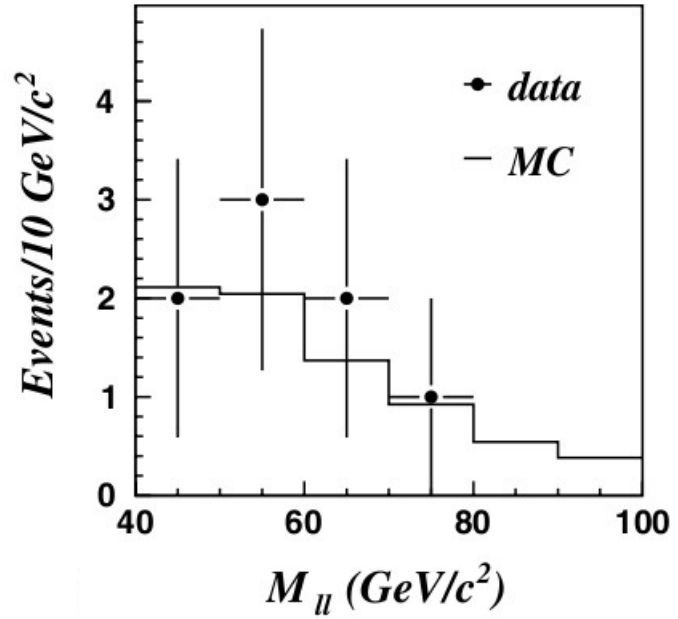
- Soft QCD can also provide **clean event signatures**.
- Exclusive production (EP) is a **search channel** for new physics / Higgs Boson.
- **Observed** EP in the dijet, dielectron and charmonium channels.



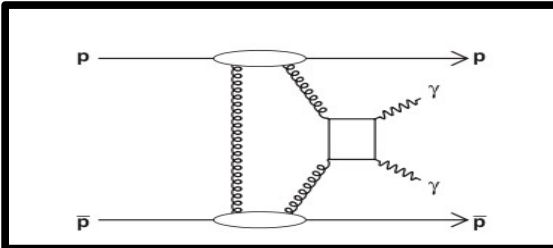
PHYSICAL REVIEW LETTERS 102, 242001 (2009)



PHYSICAL REVIEW LETTERS 102, 222002 (2009)



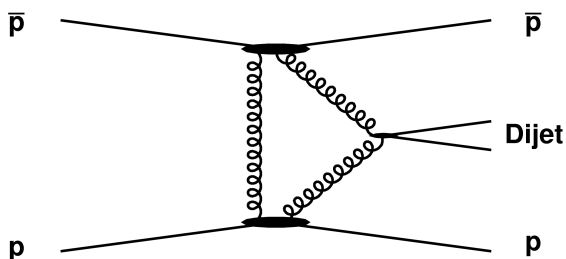
Not observed, but limits do not exclude SM calculation.



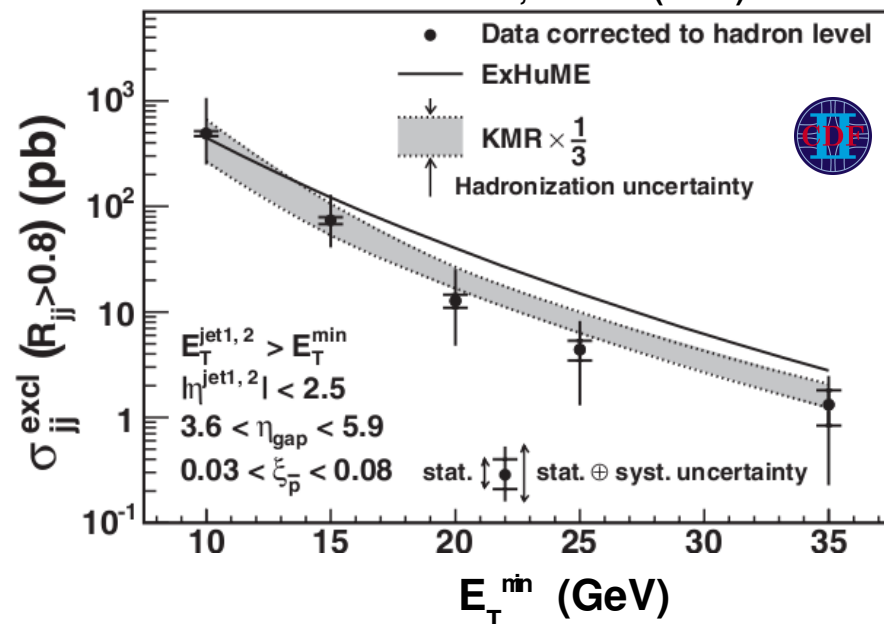
PHYS. REV. LETT. 99, 242002 (2007)

3 exclusive candidate events in the diphoton channel.

4. EXCLUSIVE PRODUCTION

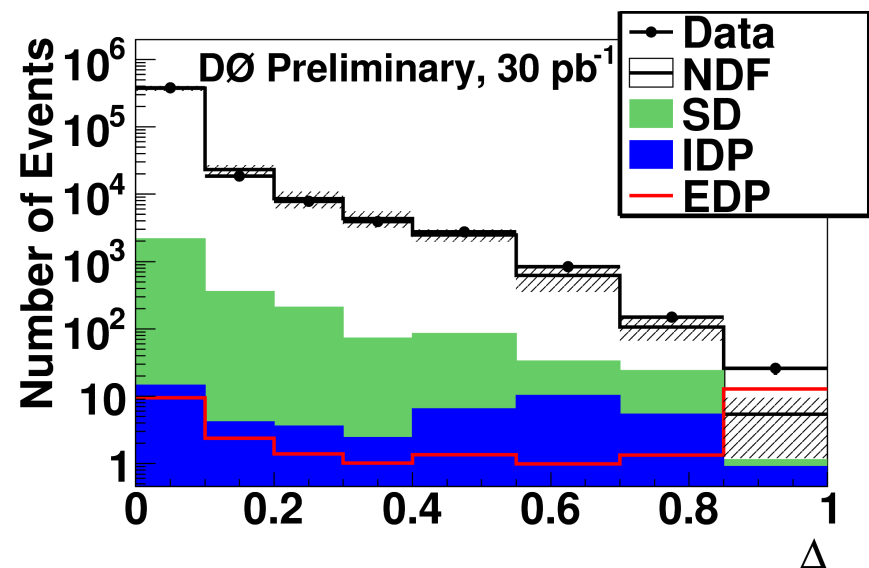


PHYSICAL REVIEW D 77, 052004 (2008)



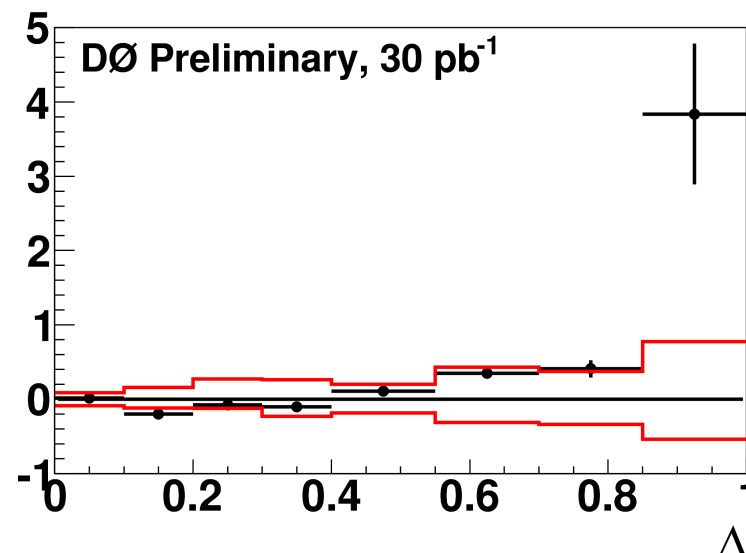
→ CDF made observation and cross section measurement of exclusive dijets.
→ Recently, D0 reported evidence for exclusive dijets at higher masses.

$|y^{j1,j2}| < 0.8$
 $p_T(j1,j2) > (60, 40) \text{ GeV}$



$$\Delta = \frac{1}{2} \exp\left(-\sum_{2.0 < |\eta| \leq 3.0} E_T/\text{GeV}\right) + \frac{1}{2} \exp\left(-\sum_{3.0 < |\eta| < 4.2} E_T/\text{GeV}\right)$$

(DATA-BKG)/BKG

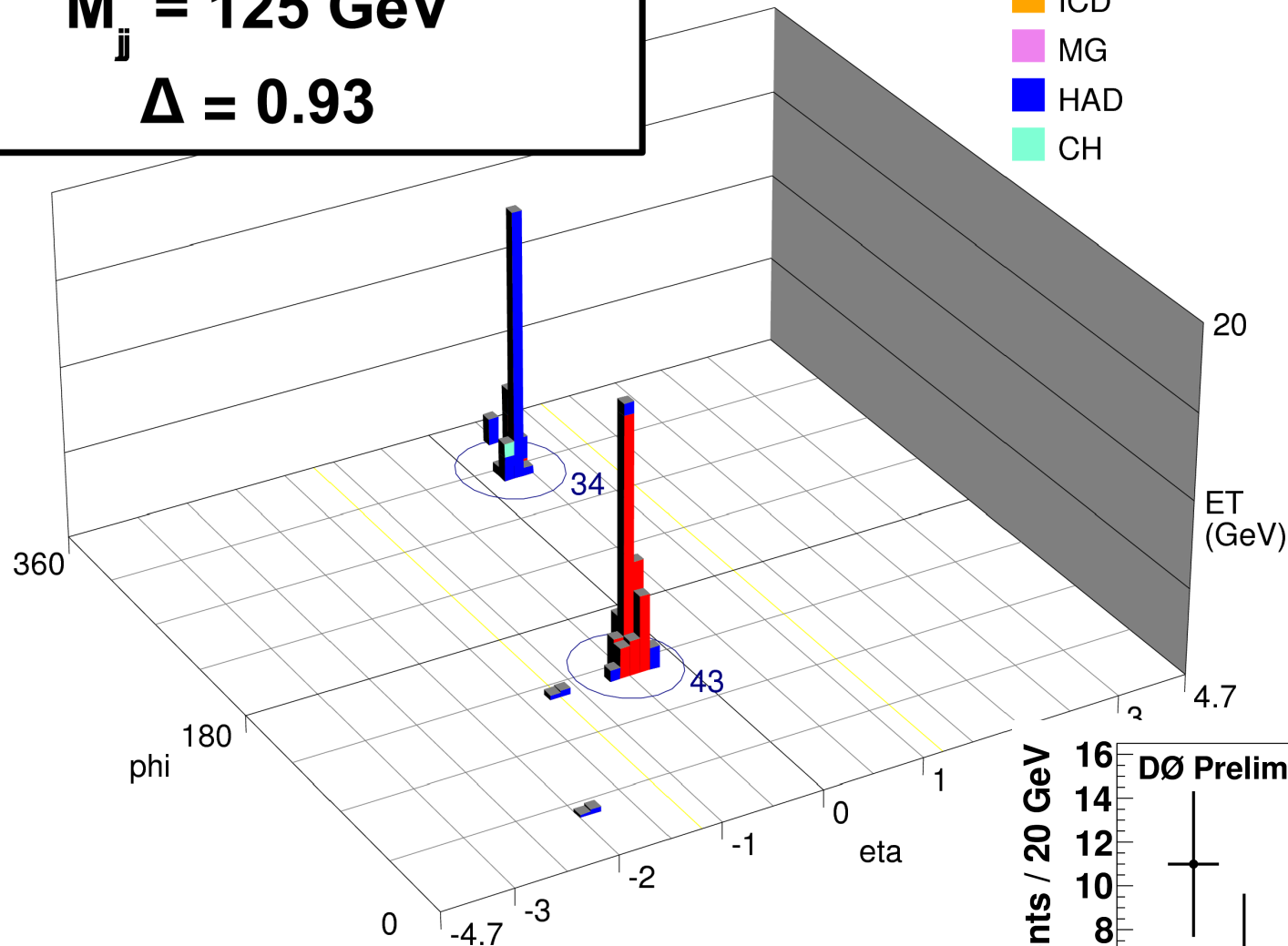


<http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/QCD/Q17/Q17.pdf>

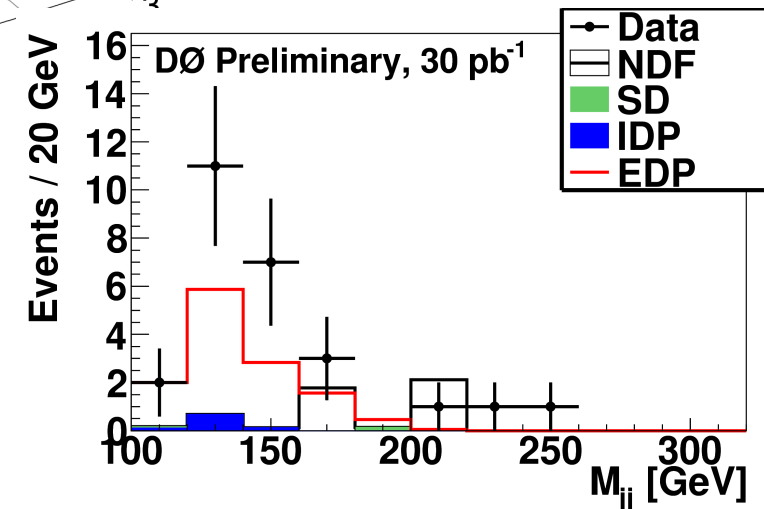
Run Number: 208856
 Event Number: 50853397
 $M_{jj} = 125 \text{ GeV}$
 $\Delta = 0.93$



EM
 ICD
 MG
 HAD
 CH



$\Delta > 0.85$
 26 candidates
 $\text{BKG} = 5.4^{+42}_{-29}$
4.1 SD evidence



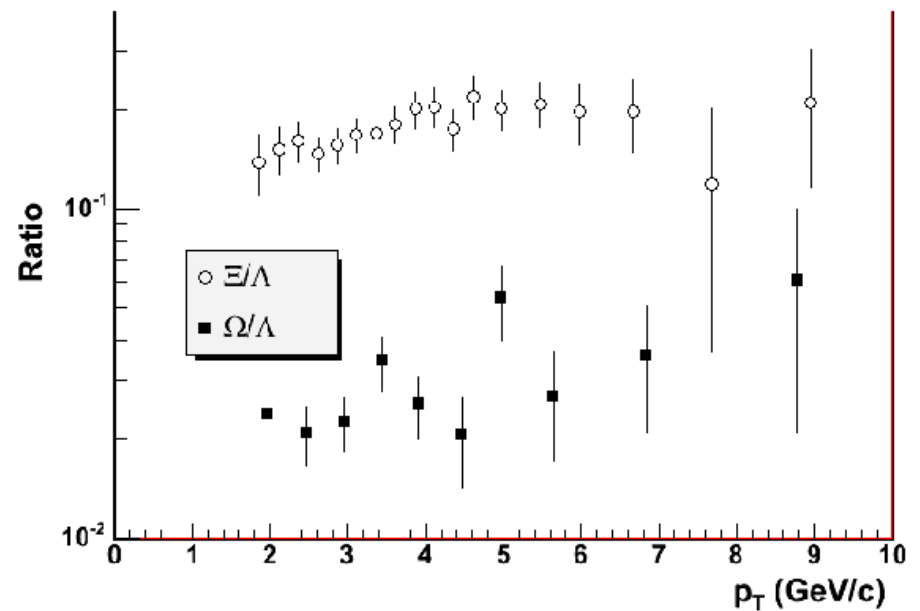
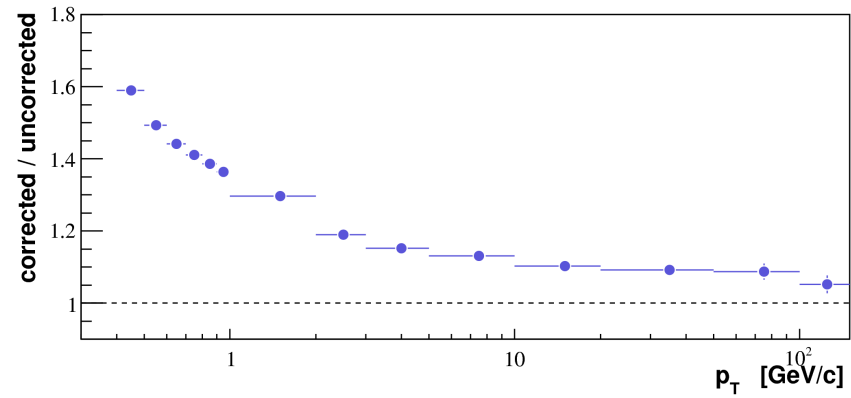
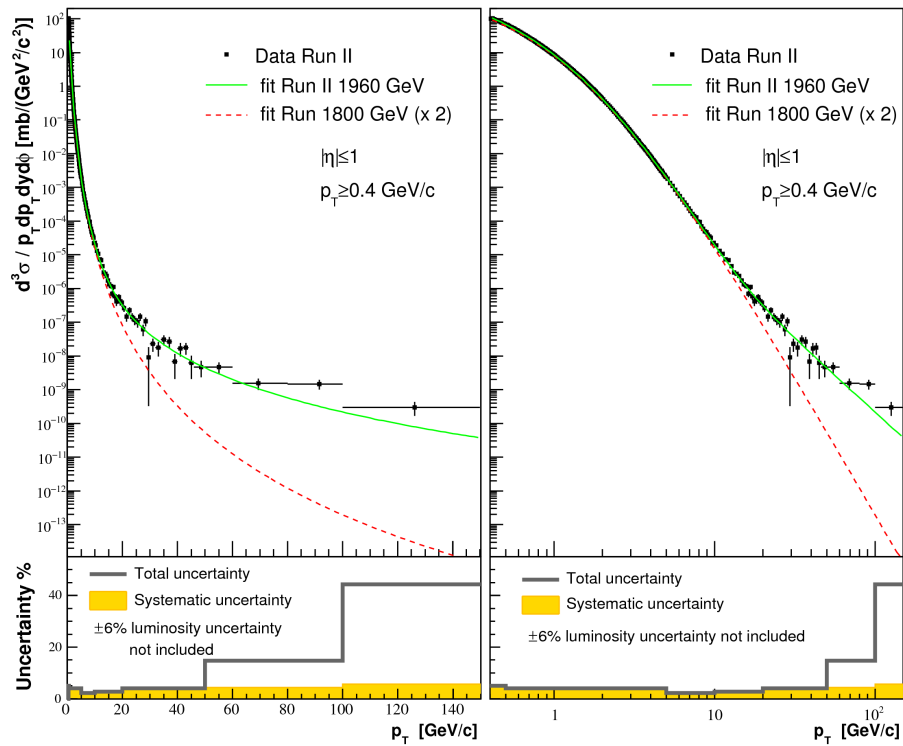
- ⇒ **Soft QCD studies at Tevatron enrich the understanding of important characteristics of hadron collider events.**
- ⇒ **With more statistics, Tevatron measurements access higher energy regions, being used to validate and tune predictions.**
- ⇒ **More data is being collected and will extend current analyses.**
- ⇒ **Tevatron → LHC extrapolations became more reliable.**

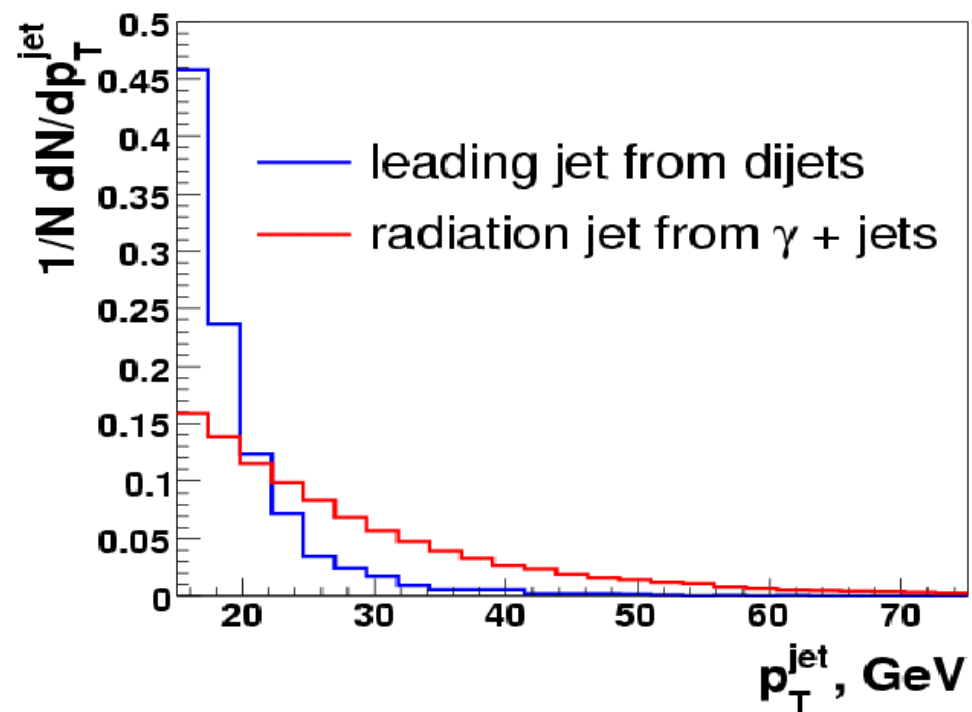


ADDITIONAL INFORMATION

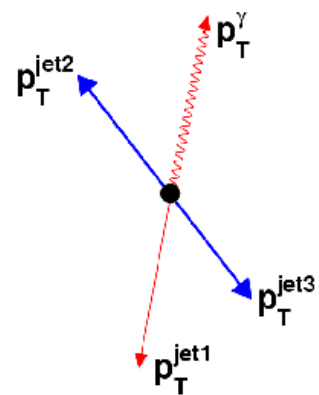
<http://www-cdf.fnal.gov/physics/new/qcd/QCD.html>

<http://www-d0.fnal.gov/Run2Physics/qcd/>

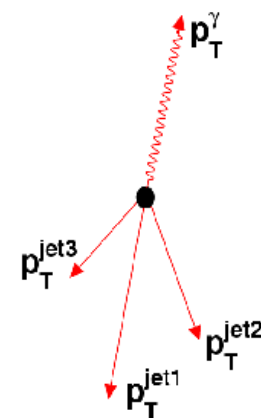


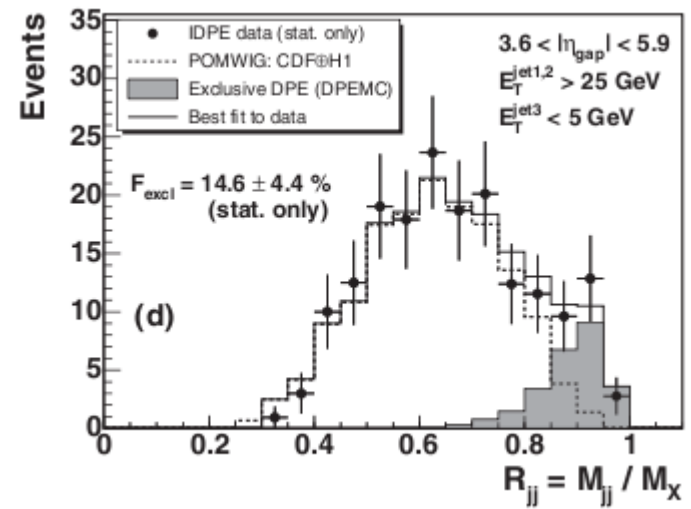
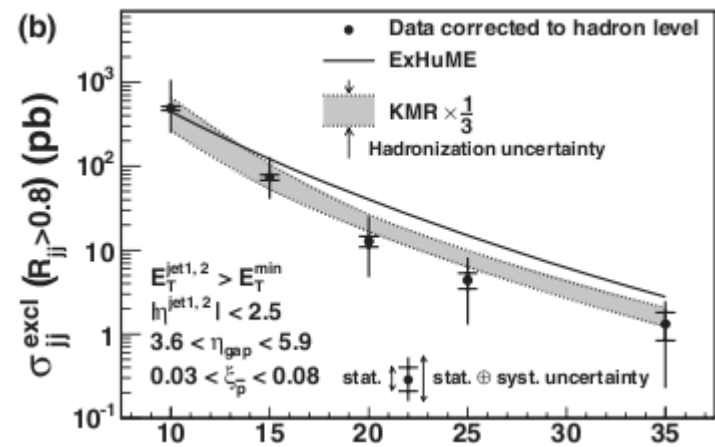
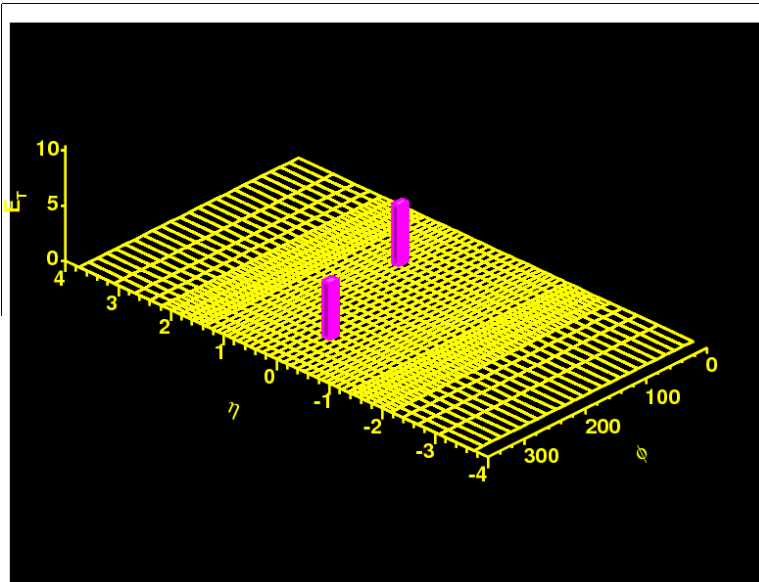


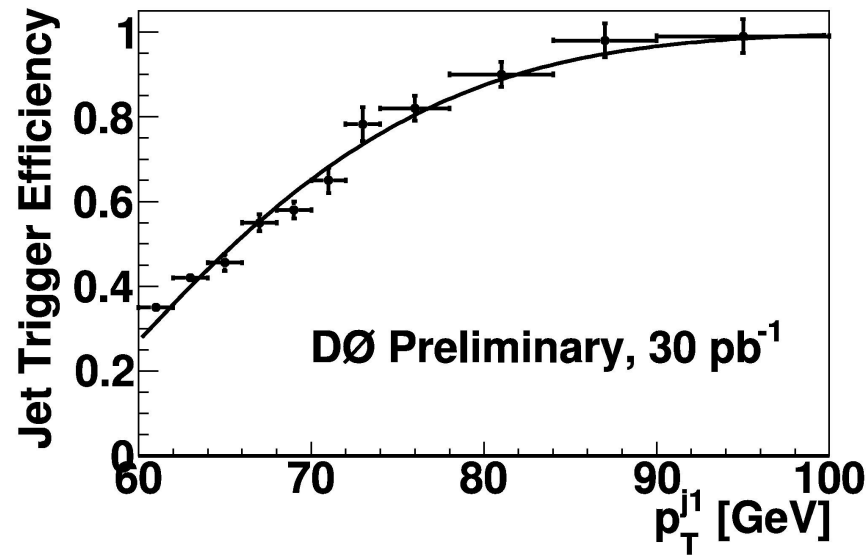
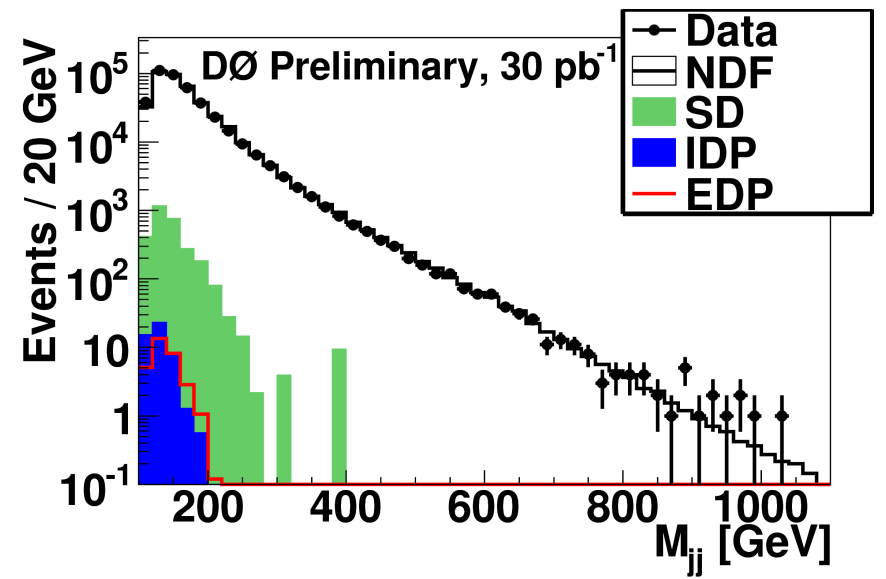
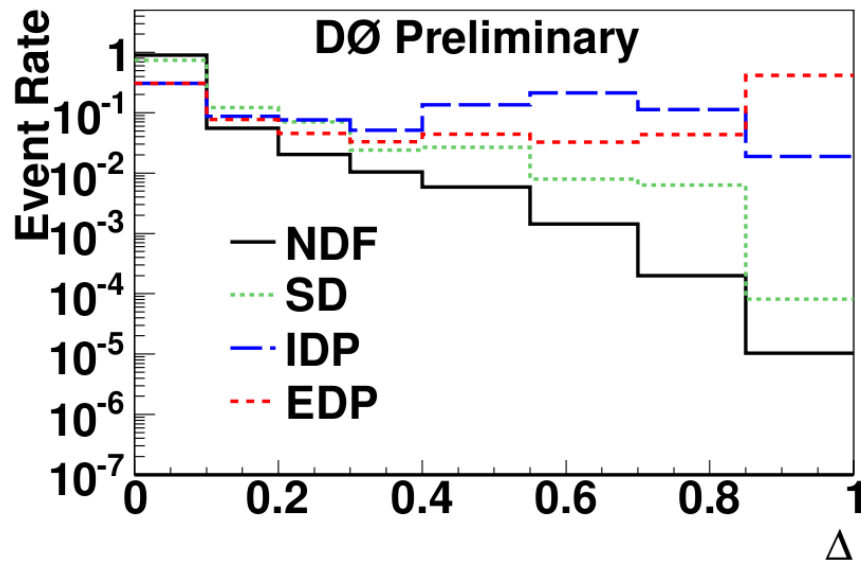
Double parton



Single Parton







Sample	NDF	IDP	SD	EDP	Data
No Δ cut	409527 \pm 24056	48.3 \pm 24.3	2930 \pm 1474	30.9 \pm 1.8	412505
$\Delta \geq 0.85$	4.2 \pm 1.6	0.9 \pm 0.4	0.2 \pm 0.2	12 \pm 0.9	26